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INVESTIGATION OF TENT HEATING ALTERNATIVES

by
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UNITED STATES ARMY NATICK
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Current military tent heaters have remained essentially unchanged since World War II. While these heaters are still effective, they can be dangerous if operated improperly and are considered by some to be unsafe. A comprehensive survey of heater manufacturers was conducted to help identify new equipment, technology, or modifications to existing equipment hopefully resulting in safer, more efficient heaters for military shelters and tents. Several conclusions can be drawn from the market survey.

First, no commercially available liquid-fueled space heaters are capable of competing with existing tent heaters on the basis of cost. Second, the no-power requirement excludes most commercial heaters from military field use. Third, the multifuel squad stove could possibly be converted for use as a small tent heater. Finally, the developing technology of thermoelectric generator power (TEG) for heaters represents an opportunity for the military to field a safer, more efficient tent heater.

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PREFACE

This report describes the efforts undertaken as part of the project T/B Systems Analysis of Tent Heating, using Project 1L62786AH98AA063 funds. This effort was initiated in FY 1988 with all research conducted by the Combat Service Support Division, Advanced Systems Concepts Directorate (ASCD), United States Army Natick Research, Development and Engineering Center (Natick). All efforts were performed during the period from October 1, 1987 to September 30, 1988.

Acknowledgement is accorded to Harry Kirejczyk, ASCD, for his insight and support of this effort, and to Joseph MacKoul, Aero-Mechanical Engineering Directorate (AMED), for lending his technical assistance.

INVESTIGATION OF TENT HEATING ALTERNATIVES

INTRODUCTION

This project represents the first effort by the United States Army Natick Research, Development and Engineering Center (Natick) to examine tent heating requirements from a macro perspective. All previous similar efforts have examined this subject area from a micro perspective, specifically in terms of equipment performance characteristics. Because of this conservative approach towards tent heating requirements, the military supply system contains only three types of space heaters: the M1941 type I, solid fuel, NSN 4520-00-257-4877; the M1941 type II, solid or liquid fuel, NSN 4520-00-927-4214; and the M1950, yukon, solid or liquid fuel, NSN 4520-00-287-3353. These heaters were developed during the first decade after World War II and have remained essentially unchanged since then. While these heaters are still highly effective, they can be dangerous if operated improperly and are considered by some to be unsafe.

In recent years, the military has changed its position on many areas, especially on the safety and efficiency of its equipment. As a result of this change, Natick funded this project to investigate tent heating from a systems perspective. During the initial stages of the project, it became apparent that heating equipment suitable for use in the military's tactical shelters would also be identified. The scope of the project was expanded accordingly to include identifying heaters suitable for use in International Standards Organization (ISO) shelters as well. In pursuing these project objectives it was hoped that new equipment, technology, or modifications to existing equipment would be identified with the end result being safer, more efficient heating equipment for shelters and tents.

Project Approach

In order to determine the state of the art in radiant space heaters, several market surveys were conducted. The first survey was conducted by mail, a second was conducted through an advertisement in the Commerce Business Daily, a third among international standardization group countries,

and a fourth through National Defense magazine. In addition, a request for information on heaters and related technology was sent to the Army Materiel Command Science and Technology Center Europe (STCEUR) scientific and technical team.

The mail survey was conducted in January 1988. A mailing list of approximately 300 companies in the United States and Canada was developed using the Thomas Register, sources solicited in previous market surveys, companies responding to heating equipment-related solicitations, and miscellaneous sources identified through the print media. Responses to the various surveys began to arrive in mid-January and continued through the end of May 1988.

Collectively, the market surveys identified about 350 sources of heating equipment overall. Of these sources, approximately 15 firms produce equipment that appeared to be suitable for tent and shelter heating. The firms were contacted for further information on specific products.

HEATER REQUIREMENTS

In all previous searches for tent heating equipment to replace items currently in the system, a rather stringent set of requirements was used. The primary requirements included the following: operation without electrical power; multifuel (gas, diesel, jet) capability; capability of withstanding rough field usage; vented operation with an adjustable heat output of at least 50,000 Btu/hr; or unvented operation only if products of combustion are not hazardous to health when operated in an enclosed area. These standards effectively eliminated the vast majority of commercial heating equipment.

Multifuel Requirement

The primary requirement, the capability of burning both liquid and solid fuels, eliminated virtually every commercial space heater. For the most part, commercially available space heaters burn either liquid fuel or solid fuel exclusively. Of those commercial space heaters that burn liquid fuels, very few are capable of burning gasoline or jet fuel. When queried about this, company representatives responded that because of the volatility of gasoline and jet fuel there is little demand for heaters capable of burning these fuels. By requiring

such a capability, the military is demanding a heater that the commercial market has declared too dangerous to produce and market. As a result, commercial liquid-fueled space heaters burn diesel fuel, light fuel oils, kerosene, or waste oil.

Most solid fuel commercial space heaters are coal- or wood-burning stoves. Ever since the first energy crisis in 1973 and the accompanying increased consumer demand for such stoves, industry has been developing newer, more efficient stoves than ever thought possible. For fixed installations, one of these solid fuel-burning stoves may be the best solution to the shelter heating problem, especially when cost, life expectancy, and fuel consumption are considered.

Nonpowered Requirement

The requirement for a heater to be operable without the need for electrical power directly contradicts the vast majority of heaters offered in the commercial marketplace. Because most nonelectric commercial space heaters are used in the construction industry where electrical power is usually available, most require power to run a blower assembly. With commercial heaters becoming more efficient, the no-power requirement should be reexamined.

In determining whether either of these two objectionable specifications for tent heaters can be modified, one has to look at specific applications of tent-heating equipment. Obviously, the military has a need for a nonpowered space heater capable of burning a variety of liquid or solid fuels. In such situations, the existing M1941 and M1950 space heaters are probably the best, if not the only, solution. However, there are very few instances when minimal electrical power or the fuel of choice is not available. For these situations a less versatile liquid or solid fuel space heater may suffice.

Heating Equipment Selection Criteria

In selecting a tent heater for various applications, a number of factors must be taken into consideration. The trade-offs and interrelationships of these factors are also very important in the decision-making process. Cost is one factor that must be considered. The cost guidance given the military has long been to buy equipment that meets a set of minimum acceptable standards and nothing more. Such a policy is aimed at making equipment utility the top priority.

A second factor, one that is often directly related to cost, is the life expectancy of the unit. The two tent heater variations currently in the system are inexpensive. The life expectancy of these units, however, is only 2-4 heating seasons.[1] For some applications, a more expensive heater with a longer life may be the better choice.

A third factor to be considered is the weight and volume of the heater, characteristics directly affecting the ease with which it can be transported. The ease of transport factor is directly related to unit application. In those instances where a unit has to be packed up and transported frequently, weight and cube are very important factors. In other instances where a heater is setup for a long period of time, or perhaps even as a semipermanent installation, a heavier, more expensive heater with a longer life expectancy may be a better long-term investment for the military. The physical footprint of a tent heater is also a factor that must be considered. With the Five Soldier Crew Tent (FSCT) about to enter the supply system, a heater with a smaller footprint than the M-41 or Yukon stove must be found or this shelter will become a four-soldier-with-stove tent.

A fourth important factor is heater operating efficiency. A heater that consumes considerably less fuel during operation may be a better choice than a more versatile heater that is capable of burning a wide variety of fuels, albeit at a lower level of efficiency.

A fifth factor deserving of consideration is the type of fuel required by the unit. Again, there may be instances where many different types of fuel may, out of necessity, have to be burned. In other instances the fuel of choice may be available in abundance. Given the military's designation of JP-8 as the single fuel for the future, perhaps multifuel capability is nothing but an expensive luxury.[2]

Finally, the complexity and frequency of maintenance required by a heater must be considered. If a heater requires frequent or tedious maintenance procedures, the user will be inclined to postpone such efforts until absolutely necessary. As evidence of this tendency, it has been reported that many incidents involving the current heaters can be attributed to inadequate preventive maintenance.[3]

MARKET SURVEY RESULTS

All product information received during the second quarter was reviewed and categorized according to its potential value as a tent heater. As the collected information was reviewed, it became apparent that the number of heaters adaptable for military use, even using the modified requirements discussed above, was still very limited. Nevertheless, four types of heating equipment appeared to have military potential.

Liquid-Fueled Heaters

The first type of commercial heating equipment that appears to have a potential use in the military is the liquid-fueled construction heater. As noted in an earlier study,[4] there are no commercial heaters that meet the military's multifuel, nonpowered requirement. Through the market survey, one non-powered multifuel heater was identified that may be suitable for some military applications. This heater is manufactured by the Scheu Products Company and marketed as the Hy-Lo Hard Hat Radiant Oil Heater®. The Hard Hat has an adjustable output from 50,000 to 140,000 Btu/hr; consumes fuel at a rate of 0.35 to 1 gallon per hour; weighs 28 pounds without fuel; has a 10 gallon fuel capacity; and is capable of burning No. 1 or No. 2 diesel fuel, No. 1 or No. 2 heating fuel, or kerosene.

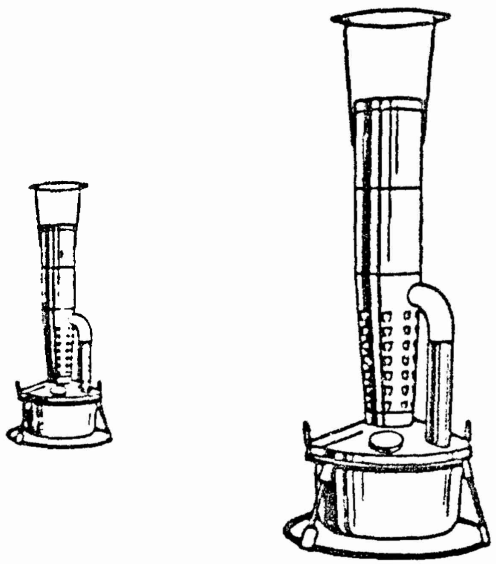
The Hard Hat Heater was originally marketed as a return stack orchard heater and was identified as such in an earlier Natick evaluation of liquid fuel space heaters.[5] At that time, the heater was pronounced too dangerous, too noisy, and of the wrong design to be used as a field heater.[6] Judging from its longevity in the commercial marketplace, however, one has to question the accuracy of these conclusions about a a space heater that has found widespread acceptance in this age of enormous product liability awards.

In quantity, the Hard Hat heater will cost well under $100. The Hard Hat is sold as a temporary heater for the construction industry and meets American National Standards Institute (ANSI) standards listed in A10.10-1970 "Safety Requirements of Temporary or Portable Space-Heating Devices and Equipment Used in the Construction Industry." Because of its considerable capacity, the Hard Hat may be suitable for use in TEMPER tents up to 64′ by 20′ configuration or possibly in the Shelter Maintenance Transportable (SMT). The Hard Hat heater is pictured in Figure 1.

HY-LO HARD HAT

RADIANT OIL HEATER

LINE DRAWINGS FOR USE IN ADVERTISING



Scheu Products Company, Inc.
P. O. Box 250 • 297 Stowell Street • Upland, Calif. 91786 • 714/982-8933

Figure 1. Scheu Hard Hat Heater ®

Ship Cabin Heaters

A second category of heaters with potential uses in the military are those sold as ship cabin heaters. These heaters are sold in both liquid and solid fuel versions, with some models capable of burning both types of fuel with only minor modifications. In general, these heaters seem ideal for military applications. All models identified are compact, lightweight, and rugged since they are designed to withstand the rigors of oceangoing vessels. When purchased in quantity, these heaters will be in the $100. to $200. price range, making them competitive with current heaters.

The primary drawback of these heaters is their relatively low heat output of under 15,000 Btu/hr. Despite their limited capacity, these heaters may be viable heating alternatives for use in the Five Soldier Crew Tent (FSCT).

Vehicle Heaters

The greatest number of heaters with the potential for military use fit into the vehicle heater category. Without exception, these heaters require either 12 or 24 volts dc power for operation. As such, these heaters do not meet the nonpowered requirement. With some type of vehicle expected to be nearby most shelters and tents in future battlefields, however, these heaters may be a viable option.

With few exceptions, modern vehicle heaters are compact, lightweight, and highly fuel efficient. Advanced designs incorporate microprocessor controls, automatic flameout protection via fiber optics, and digital quartz timers. These vehicle heaters are produced by the following companies: Espar Heater Systems, Hunter Manufacturing, and Webasto Heater Incorporated. All three companies market their product line worldwide, making spare parts and service readily available. Vehicle heaters can be purchased as either air or coolant heaters, depending on the desired application, and burn a variety of liquid fuels. Vehicle heaters are produced with heating capacities ranging from 5,000 to 110,000 btu/hr.

Alternative Heater Concepts

Thermoelectric Generation Heaters. One developing technology that deserves additional investigation is thermoelectric generation (TEG). In heating applications, TEG energy is used to power heaters that normally require 12 or 24 volts dc for operation. The primary component of such a heater is the thermoelectric generator. A TEG generator produces electrical power by applying heat from the combustion of fuel to one side of a solid-state energy converter while simultaneously cooling the other side of the converter. The resulting temperature differential causes dc power to be produced. In colder climates, more dc power is produced because the temperature differential is greater than at higher temperatures. Most TEG converters consist of lead-telluride thermoelectric elements hermetically sealed in high temperature steel alloy.

The TEG converter can be either air- or liquid-cooled, depending on the heater application. Depending upon whether the unit is air- or liquid-cooled, TEG heaters possess only two or three moving parts. In air-cooled models, the only moving parts are the electric fuel pump and the combustion blower. Liquid-cooled models require an additional pump to circulate coolant.

The unique feature of TEG-powered heaters is that most require external power from a battery for starting purposes only. One model requires no external power at all. Once started, the dc current produced by a TEG heater can be used to recharge the starting battery, or to power computers, lighting or any other battery-operated device. In TEG power source type heaters start-up, operation, and heater shutdown are regulated by a microprocessor-based system controller. TEG power source type heater operation requires only the activation of an ON/OFF switch. Within several minutes of start-up, an indicator light will signal that the starting battery has been recharged. Once the indicator light is illuminated, the starting battery may be disconnected and the TEG-produced DC power used for other purposes.

At the present time, four TEG-powered heaters are close to commercial production. The first TEG-powered heater identified is being developed by Global Thermoelectric and is being marketed as the Manpack Generator. The Manpack Generator produces 10,000 Btu/hr of heat, 120 watts of DC power, weighs less than 40 pounds, and has a cube of approximately 1.5 cubic

Figure 2. Global Thermoeletric Manpack Generator R

feet. The Manpack Generator is marketed primarily as a power source. Estimated cost of the Manpack Generator is $ 5000. in quantity. A photograph of Global's Manpack Generator is shown as Figure 2.

A second TEG-powered heater identified is being developed by New Born Industries and is being marketed as the Thermo Electric Heater Portable (TEHP). The TEHP produces 10,000 Btu/hr of heat, 40 watts of dc power, weighs less than 40 pounds, and has a cube of approximately 1.5 cubic feet. The TEHP will be marketed primarily as a heater. Expected cost of the TEHP is $3500. in quantity. A photo of the New Born Industries prototype TEHP follows in Figure 3, while a photo of a military version of the TEHP currently in production follows in Figure 4.

The third and fourth TEG-powered heaters are developed by Teledyne Energy Systems, with one to be marketed as a mobile electrical power source and the other to be marketed as a self-powered heater. Teledyne's TEG power source heater is very similar to Global's Manpack and NBI's TEHP in that it requires a battery for ignition and operation, and features simple single-switch operation. This heater produces 10,000 Btu/hr, 120 watts of dc power, weighs 45 pounds with 12 hours of fuel, and has a cube of 1.8 cubic feet. This first heater is expected to cost $5000. in quantity. A photo of Teledyne's TEG power source heater follows in Figure 5.

Teledyne's self-powered heater (SPH) is different from the other TEG heaters identified. The SPH has a capacity of 5,000 Btu/hr, needs no battery for ignition or operation, weighs 35 pounds, and has a cube of 2.5 cubic feet. The SPH does not, however, produce any surplus dc power since it is designed primarily for use as a heater rather than a power source. The SPH uses the TEG power produced to run a blower assembly that not only circulates the heat generated, but enhances combustion as well. Since heating is its primary function, expected cost of the SPH is only $1,000. with the price reduced to $500. when large quantities are purchased. A photograph of the SPH is included as Figure 6.

The primary difference between the Global's Manpack Generator and NBI's TEHP is that the Manpack was designed primarily to be a power source, while the TEHP was designed to be used as either a heater or a power source. Teledyne's TEG power source heater, like the Manpack, was designed primarily for use as a power source. The intended use results in the cost difference between the units. The most expensive

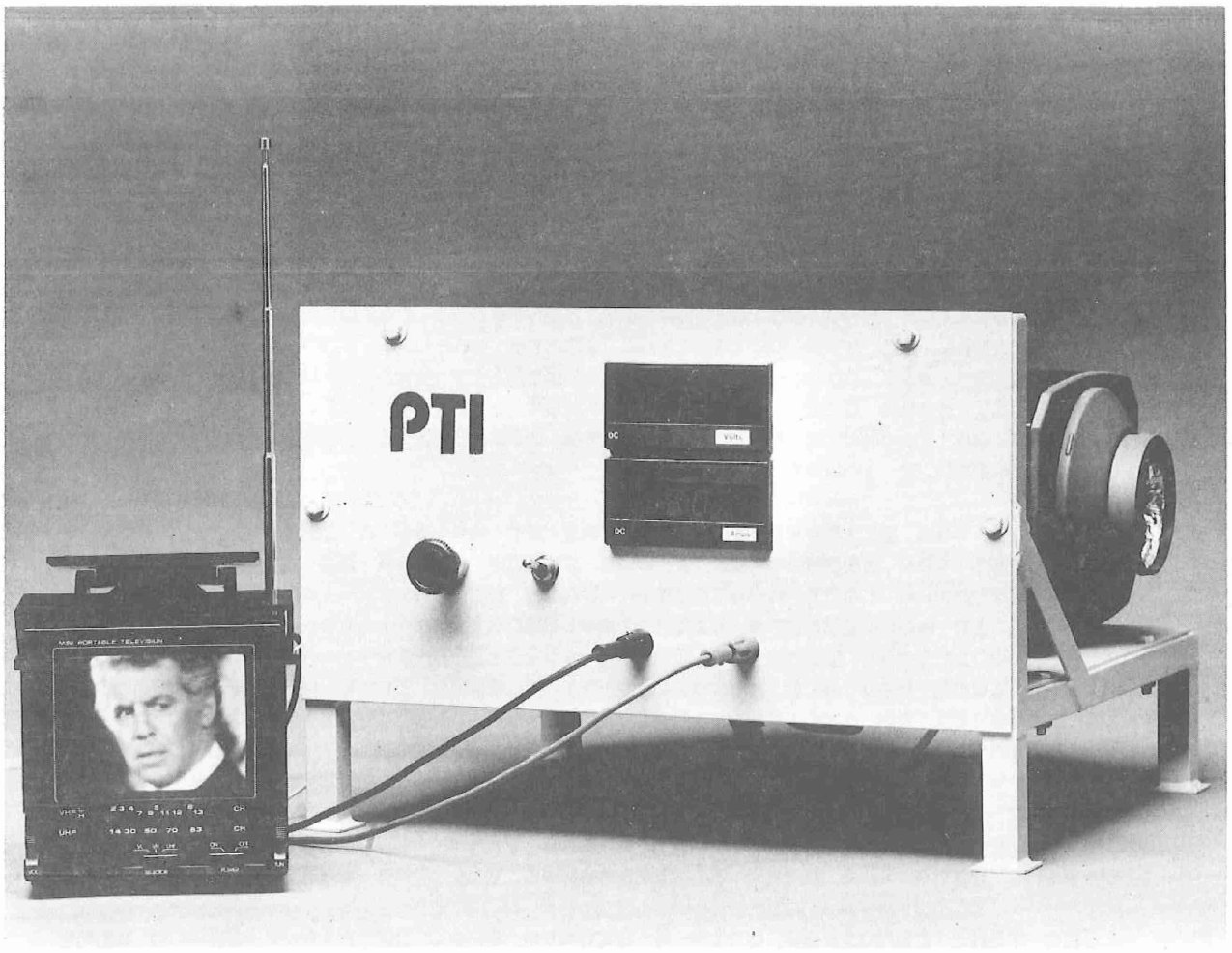


Figure 3. New Born Industries Thermo Electric Heater Portable (TEHP)

component of both heaters is the TEG package. Generally, the more power that is desired, the higher the cost of the TEG package, which increases the cost of the dual-purpose heaters.

In comparing the three power source type heaters, the Manpack Generator and Teledyne's TEG power source heater are more expensive than the New Born Industries TEHP heater for several reasons. First, the Manpack and Teledyne's TEG power source heater produce more dc power than the TEHP. Second, the Manpack and Teledyne's TEG power source heater are more expensive because both manufacturers fabricate their own heater assemblies and TEG package. Third, the research and development costs of developing and producing both the TEG package and the heater assembly must be recovered.

The New Born Industries TEHP incorporates one of several commercially available vehicle heaters described previously. By doing so, NBI not only reduces the overall cost of its TEHP but also allows the company to focus its resources on the much more critical TEG package. The use of commercially available heaters also allows the user to take advantage of an in-place dealer network, which provides a ready source of service or spare parts when required. Accordingly, NBI has lower research and development costs to recover, lower costs of distributing and producing spare parts, and a more reliable heater assembly since the commercially available heaters presumably have had all the "bugs" worked out. Collectively, these three factors allow NBI to offer its TEHP for sale at a considerably lower price.

One of the primary advantages of using a TEHP for tent heating is the amount of floor space saved by not using one of the current tent heaters. When properly installed and operated in accordance with instructions listed in the space heater technical manual (TM 10-4500-200-13), either of the current tent heaters requires 81 square feet of tent space. This amounts to approximately 25% of the available floor space in a standard 16' by 20' TEMPER or GP tent. This means that for every four tents requiring heat, the cost of one tent is saved by using a TEG heater/power source. These savings can only be realized, however, if the TEHP is placed outside of the tent with the heat distributed via the tent duct system.

The TEHP requires only 2 square feet of floor space when used inside a tent. Since the entire TEHP remains cool to the touch, it can be placed very close to the tent wall. The only fire hazard comes from the TEHP's flexible exhaust tubing which must be slipped through a flame-resistant collar before

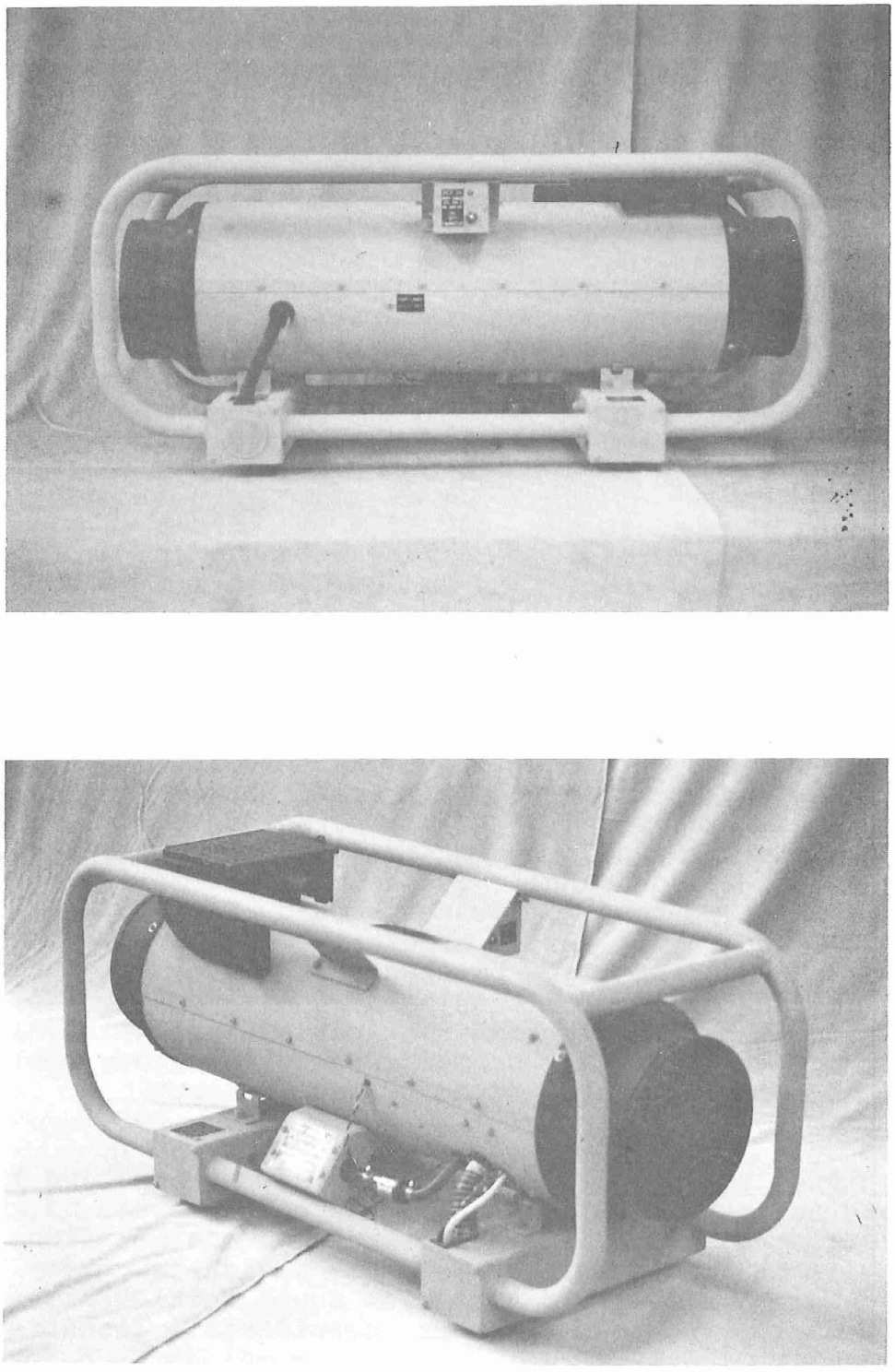


Figure 4. New Born Industries Military Thermo Electric Heater Portable

passing the tubing through any flammable surface, including a tent wall.

One unknown quotient at this time is what size capacity a TEG heater must have to sufficiently heat a TEMPER tent. The desired capacity of a TEG heater will directly affect its physical dimensions, which in turn will affect any floor space savings resulting from placement of the TEG heater inside a tent or shelter. The question thus becomes not whether there will be floor space savings by using TEG heaters, but rather how great the savings will be. Previous Natick studies have indicated that an output rate of 35-40,000 Btu/hr may be acceptable for a TEMPER tent with cotton liner insulation.[7] A heater of this capacity should also adequately heat an ISO shelter. Assuming that current heater technology is used, a TEG heater/power source with a capacity of 35,000 Btu/hr and a footprint of less than 3 cubic feet can be expected.

A second unknown is the cost of a TEG heater with a 35,000 Btu/hr capacity. Projected cost of a 35,000 Btu/hr TEG heater is approximately $3,500. each in production quantities, with no significant decrease in price until large quantities are purchased. A 35,000 Btu/hr TEG heater should be capable of producing a minimum of 100 watts of 12 volts dc power, with 500 watts a distinct possibility.

With the price of tents running at only $5.40 per square foot for GP tents and $6.30 per square foot for TEMPER tents, the cost of a dual purpose TEG heater/power sources will be unrecoverable with the price of existing tent heaters firmly in the $ 200 - $ 400 range. The higher cost of a larger capacity SPH type heater, however, could easily be justified by the versatility of having a portable heat source that can be easily moved from place to place, can be used for a variety of heating tasks, is much simpler and safer to operate, runs completely automatically, and requires minimal maintenance. Further breakthroughs in thermoelectric technology could also lower the cost of a large capacity TEG heater.

Multifuel Squad Stove Heater. Another alternative that deserves further investigation is the possible use of the multifuel squad stove as a heater. Since one multifuel squad stove will be issued for every five individuals, every FSCT will contain a stove. If this same squad cooking stove could serve a dual purpose as a heater, considerable logistics savings will result. The multifuel squad stove weighs 2.75 pounds without fuel, is capable of burning all types of liquid fuels

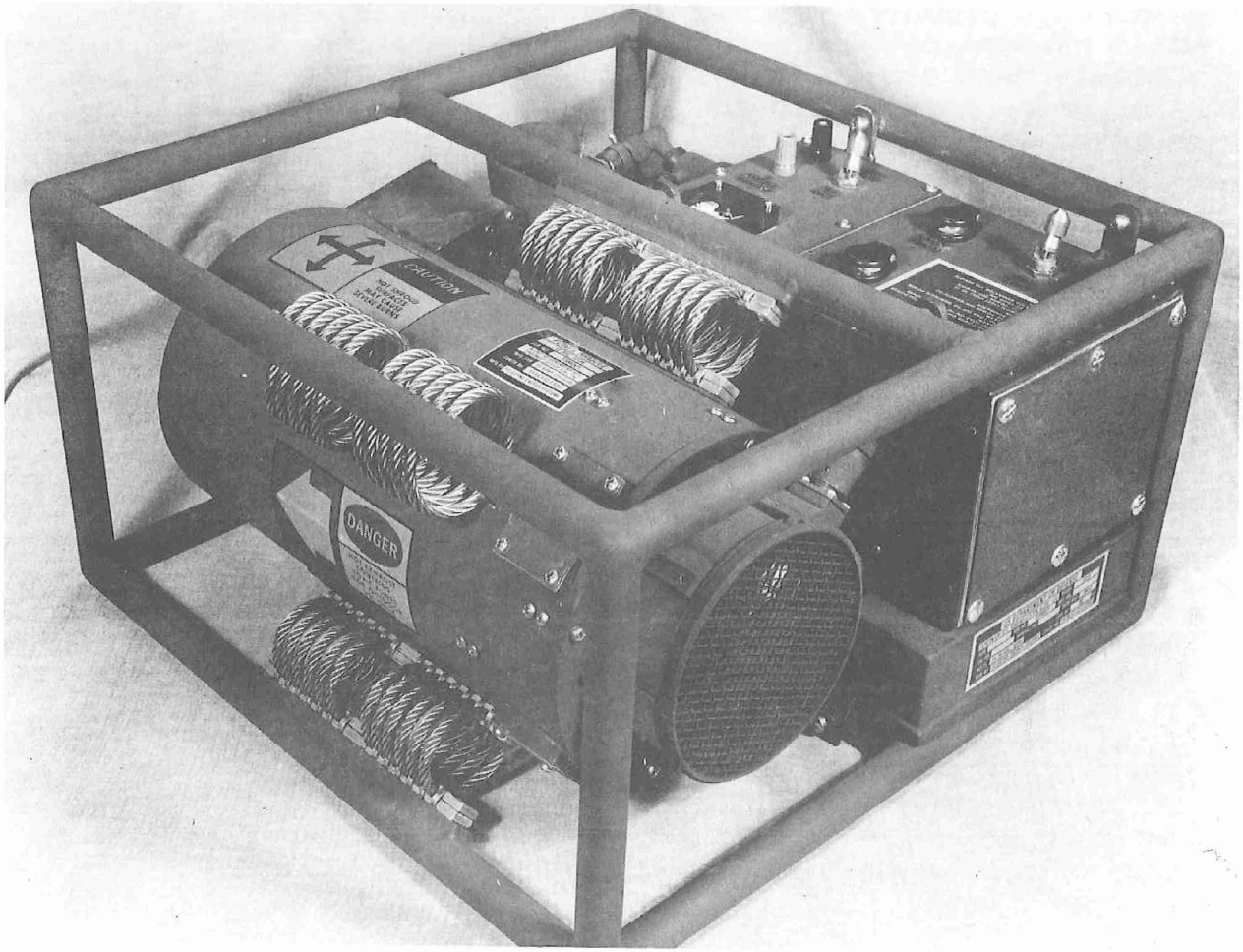


Figure 5. Teledyne TEG Power Source Heater

with only minor adjustments, and is designed for indoor or outdoor use. Depending on the type fuel used, the multifuel squad stove produces from 8500 to 10,000 Btu/hr.

The conversion of the multifuel squad stove to a heater would involve installation of a perforated cover to provide more uniform air intake and heat distribution, and attachment of a length of stove pipe to ventilate exhaust gases from the tent interior. Estimated cost of a cover and vent stack should add only about $30 to the cost of a stove if purchased in large quantities.

Conceptual Nonpowered Heater. One way to lessen the high cost of TEG heat is to reduce the amount of power a given unit produces. A conceptual nonpowered heater (NPH) would need no battery for ignition or operation, have a variable heat output from 15-45,000 Btu/hr, of dry, breathable heat, weigh under 50 pounds, and have a cube of 3 cubic feet or less. An NPH would not, however, produce any surplus DC power since it would be designed primarily for use as a heater and not as a power source. An NPH would use the TEG power produced to run one or more blower assemblies, with one used to circulate the heat generated and the other used to enhance combustion. Because heating would be the NPH's only function, prototypes should be considerably less expensive than TEG power source heaters, with production units having a price of $ 3,500. or less in quantity.

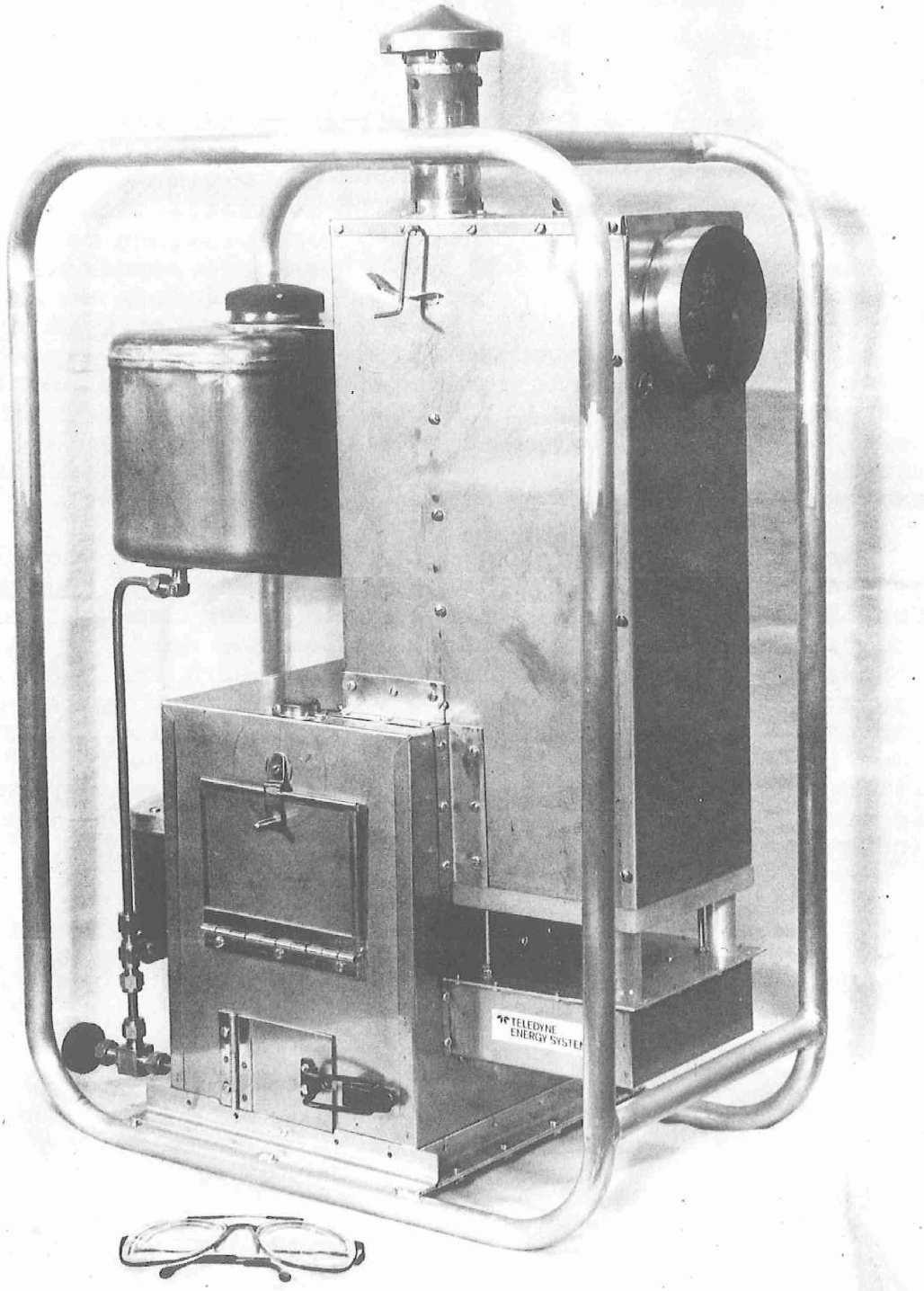


Figure 6. Teledyne Self Powered Heater (SPH)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

After completing the data collection and analysis, several conclusions may be drawn.

First, there is no commercially available liquid-fueled space heater capable of competing with existing tent heaters on the basis of cost. Second, before more commercial heater manufacturers can be induced to develop heaters suitable for military field use, the nonpowered requirement must either be eliminated or changed to allow reduced or low levels of power. Third, the multifuel squad stove could be easily converted for use as a small tent heater at a very minimal cost. The use of this item as both a squad stove and a squad tent heater will help to lighten the soldier's load and reduce the logistics burden.

Finally, the developing technology of thermoelectric generator power (TEG) for heaters represents an opportunity for the military to not only field a safer, more efficient shelter and tent heater but to reduce the need for small generators in the field, decrease man-hours for heater operation and maintenance, and make more tent space available for use. By making a commitment to TEG heating technology now, the military can specify desired features to industry without incurring huge research and development expenses because the potential for sales to the commercial trucking industry of nearly identical units is enormous.

Recommendations

Based on the preceding conclusions, the following recommendations are offered:

- Possible use of the multifuel squad stove as a heater should be investigated further.

- The military, through Natick, should further investigate the use of TEG heaters/power sources.

- All soon-to-be-available TEG heaters/power sources should be tested to determine the levels of heating capacity and power needed for future battlefields.

- Any new family of tent heaters should include both a nonpowered SPH type TEG heater and a non-TEG heater because each offers distinct advantages.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-93/022 in the series of reports approved for publication.

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